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OPTIONS FOR LHC SAFETY-ALARM TRANSMISSION

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Abstract

The LHC safety-alarm system needs, for reliability reasons, two different media to transmit the alarms to the CERN Safety Control Room. This is a requirement of the French regulatory authority (Direction de Sûreté des Installations Nucléaires de Base).
This paper examines the safety systems currently in use at CERN, with particular emphasis on the methods used for transmission of alarm information across the site. The general requirements for transmission of alarms are described. Several options for transmission of LHC safety-alarm information are compared: fieldbuses, telecommunications networks with analogue voice or ISDN lines, the time-division multiplex system, and packet switching 'mesh' networks. The reliability of each of these solutions is estimated, and different topologies for physical links described and compared. It is shown that options are available which give an accepted level of reliability, obviating the need for hard-wired connections.

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1 INTRODUCTION

'Level-3' alarms at CERN are alarms raised in situations endangering people and requiring immediate action by the fire brigade. Level-3 alarms concern the whole of CERN, that is the Meyrin, Prévessin and LEP sites. Their main users are the firemen in the SCR (Safety Control Room).The level-3 alarm system comprises the following detection equipment on the spot:

- fire detection equipment,
- flammable-gas detection equipment,
- emergency stops,
- miscellaneous.

The first three categories cover more than 90% of the level-3 alarms.

Signals are transmitted via the communication systems. The data-processing system is the main one which provides the SCR with the details (type of alarm, location, description, etc.). This system is backed up by a hard-wired system permitting lower-grade operation in the event of the failure of the main system.

Data-handling systems such as the Central Alarm Server (CAS) and the Technical Data Server (TDS), associated with the existing communication networks, make it possible to manage the alarms. The alarms are displayed on workstations or on wall-mounted panels.

For organizational and geographical grouping, CERN has been divided into 34 areas. A local panel in each area shows the alarms that may occur.

2 GENERAL DESCRIPTION

In LEP and increasingly on the Meyrin site all level-3 alarms are transmitted to the SCR and to the Technical Control Room (TCR) via a computer network and are displayed as a text message on a terminal. At present the CAS handles only 3640 alarms of the 16854, the remaining alarms not yet being computerized.

The redundancy required by the 'Installations Nucléaires de Base' (INB) rules is achieved by means of a hard-wired network [1]. All devices generating an alarm of level 3 are connected to the SCR. In LEP and progressively on the Meyrin site these hard-wired signals are transmitted via a local panel (one *for each defined area*) which displays the location of the alarm source. The hard-wired signal causes an LED to blink on the local synoptic panel indicating the building from which the alarm comes and the type of alarm.

Apart from alarms from the emergency telephones, an incoming alarm causes an LED to blink faster. When the detector that caused the alarm is reset to zero the corresponding LED remains bright; should the alarm(s) vanish then the LEDs will go off. Transient alarms are also handled but will only be cleared after the reset of the detector and the disappearance of the alarm. A 'General Alarm' summary signal from the local synoptic panel is always transmitted to the SCR; this signal indicates the area concerned. Only a reset of the local panel will turn off this 'General Alarm' in the SCR.

After the double safety-alarm transmission system had been put into service for LEP the same approach was adopted for the modernization of the other CERN areas. The SPS areas have been almost completely renovated as well as the Meyrin site where the oldest fire and flammable-gas detection systems have been replaced by modern ones [1].

3 LHC AL3S RECOMMENDATIONS

The recommendations for the LHC safety-alarm system are structured in General Recommendations, Technical Recommendations, Recommendations for Further Work, Standards and References. The Technical Recommendations state the following:

- ‘Two completely independent, diversely redundant, dedicated alarm transmission systems shall be installed. Hereinafter, these two systems are named *Safety-Alarm-Transmission system (SAT)* and *Safety-and-Technical-Data system (STD).’*
- ‘SAT and STD shall be designed and installed so as to exclude for the entire length of all transmission paths, as far as possible, any common-cause failure. Amongst others, this shall apply in particular to separate routing and to separate power supplies, including the stand-by sources.’
- ‘Alarm systems, and both the SAT and STD throughout the entire lengths of their transmission paths, shall be permanently and automatically supervised for correct functioning. Any malfunction or unavailability shall be signalled to the technical monitoring centre, as well as to other users as required.’2]

These recommendations are self explanatory and imply the evaluation of several options for the alarm transmissions.

4 OPTIONS

4.1 Fieldbus

The fieldbuses provide a valuable solution for the transmission requirement of the SAT system. CERN has recommended the use of three fieldbuses: FIP, CAN, PROFIBUS. However in this context of safety alarms, where communication must be provided over a long distance, PROFIBUS (PROcess FIeld BUS) seems the most appropriate candidate. This bus can be deployed over a distance of up to 50 km, using optical fibres. The use of a specific optical coupling device may provide a redundant transmission of the signal on two different optical fibres. This bus is a low-cost option for the SAT. Up to 126 Programmable Logic Controllers (PLC) could be connected in this way. PROFIBUS exists in three different flavours: DP, FMS and PA. PROFIBUS-DP (Decentralized Peripheral) would provide a deterministic solution: a master PLC polls all the slave stations at a defined frequency. All the stations are supervised and unavailability is automatically reported. The dimensioning of the network shall be done according to distance, the number of PLCs, and the expected data-acquisition frequency. Considering the LHC's low radiation level [4], we could consider two half-loops circulating in the drains. Locally on each safety zone the PLCs could exchange data on copper cables, and the long-distance data exchange could be done using the optical fibres. Redundancy of master and slaves could be foreseen as well even on a single network, but they would use different physical addresses.

PROFIBUS-FMS, an asynchronous messaging system, is not suitable in this case, because a client application will never be informed that a packet has been lost.

PROFIBUS-PA implements the same protocol as PROFIBUS-DP but it only uses copper cable with the electrical supply carried by the bus. It is mainly used by the chemical industry where remote sensors need to be fed by the bus itself. PROFIBUS-PA is also slower than DP [5].

4.2 The telephone network

The CERN internal telephone service is provided by a distributed Private Automatic Branch Exchange (PABX). Various switching nodes of this PABX are located on the Meyrin and Prévessin sites, and on most of the LEP sites. The nodes are interconnected by high-speed time-division multiplex (see below) links operated by CERN. These links pass over a fibre-optic network (principally surface links) and a coaxial-cable network in the SPS and LEP tunnels.

The telephone service is extremely reliable. One estimate of the availability of a similar telephone network including distributed links is 99.73%. Clearly, therefore, the telephone network is a possible solution for the transmission of level-3 alarms. Indeed, many alarm systems world-wide are implemented in this way.

A particular problem which would have to be resolved if this solution were to be adopted concerns the emergency telephones. It is currently planned to modify the cabling of the emergency telephone voice connection so as to route it to the nearest switching node, rather than bringing the connection to the node in LEP Point 1 as at present. Clearly therefore the associated alarm signal cannot be transmitted along the same path and to the same node. There are several possible solutions to this problem; these are beyond the scope of this paper.

4.3 The time division multiplex system

The time-division multiplex (TDM) network mentioned above could in itself be used to transmit alarm signals, without involving the telephone switches.

Equipment is available on the market to collect alarms, and transmit the alarm information over point-to-point TDM links to a central location. Generally packet-data protocols such as TCP/IP and X.25 are used for this transmission.

TDM networks are used by public (telephone) network operators for long-distance links to interconnect their switches; consequently the equipment is designed for very high reliability. Moreover a new system of TDM known as Synchronous Digital Hierarchy (SDH) is being introduced. SDH networks are often implemented in a self-healing ring topology: the network automatically reconfigures to survive any single malfunction.

4.4 Meshed network.

Another interesting alternative to design the LHC safety systems, and more particularly the STD, would be the deployment of a meshed network on the LHC area. Meshed networks [6] are widely used in public data-communication networks and in some local area networks. Their main characteristic is to provide alternative transmission paths between the nodes. Successful operation of a such a data-communication network is critically dependent on the provision of an adequate routing algorithm. Route selection within an irregular mesh is a complex process. It depends both on the loading of the network and the number of switching nodes traversed. The routing algorithm tries to ensure a systematic progression of each packet from its source to the destination. Certainly the routing algorithm must be capable of re-routing the traffic in the event of the failure of some part of the network. The ATM

(Asynchronous Transfer Mode) network can be configured as a mesh; it uses the PNNI (Private Network Network Interface) routing mechanism. ATM and its routing principle are currently being tested at CERN around the SPS [7] and are considered as a possible candidate for the LHC real-time network, ensuring a permanent bandwidth and a deterministic data transmission for all real-time applications. This concept of meshed ATM network could be extended to the service network ensuring a higher data availability. The mesh could be deployed as a star to the TCR on the surface and as a ring in the LHC tunnel. The particular interest of such a meshed network complementing a specific SAT is to resolve the cabling common-mode problem. Even in the event of cable damage (with or without a common mode with the SAT) the STD data will always be re-routed successfully to the destination.

5 CONCLUSIONS

A variety of solutions exist which would allow transmission of level-3 alarm information with very high reliability. An STD based on a meshed network completed by an SAT using either circuit switching technology or a fieldbus could be considered as the starting point of a detailed study.

However, whatever system is chosen, this detailed study will have to be carried out to identify and eliminate any possible common points of failure with the data network, such as power supply, physical routing of links, and co-location of equipment. The IEC 61508 International Standard provides an extremely valuable framework to carry out this analysis. Furthermore, specification and discussion should start as early as possible with the people in charge of the LHC networks.

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